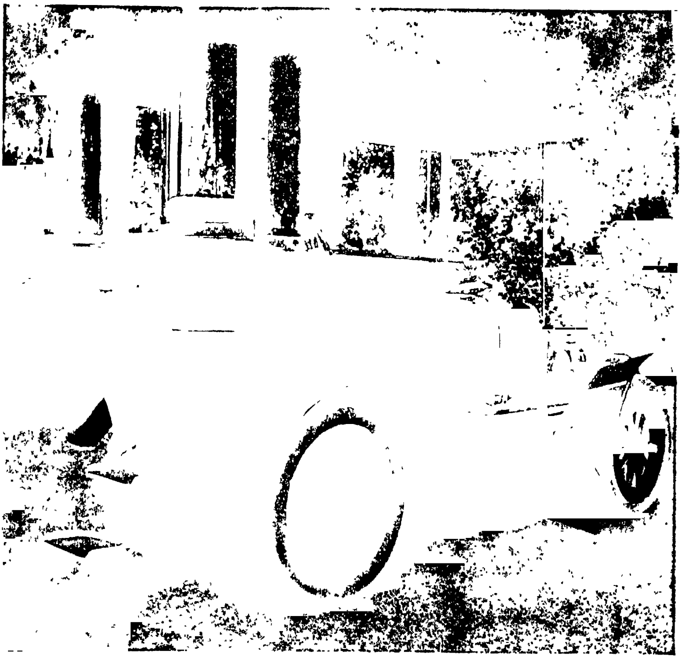
IGNITION DEVICES

FOR

GAS AND PETROL MOTORS



KING EDWARD'S 22 H.P. MOTOR CAR.

(Manufactured by the Daimler Motor Co., Ld., Coventry.)

IGNITION DEVICES

FOR

GAS AND PETROL MOTORS,

WITH AN INTRODUCTORY CHAPTER

TREATING SPECIALLY OF

STRUCTURAL DETAILS, CHOICE, AND MANAGEMENT OF AUTOMOBILES

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Fully Illustrated

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ILLUSTRATIONS.

INDEX.

A

B

C

I

J

L

M

N

O

P

R

S

T

IGNITION DEVICES.

SECTION I.

CHOICE AND MANAGEMENT OF AUTOMOBILES. STRUCTURAL DETAILS.

§ 1. Motor cars, motor tricycles and bicycles present so much matter of interest, and are entering so largely into our every-day life, that every one should have some knowledge of the principles of their construction. This knowledge, even though it be elementary, is absolutely necessary to the would-be purchaser, otherwise he may be led astray in the choice of a car, by its outward appearance, instead of directing his attention to those essentials on which the proper working and convenience of manipulation depend. Although modifications and improvements are being continually introduced, yet the main features of the propelling arrangements adopted by nearly all automobile manufacturers are based on the practice of the leading makers in France, where, owing to the freedom

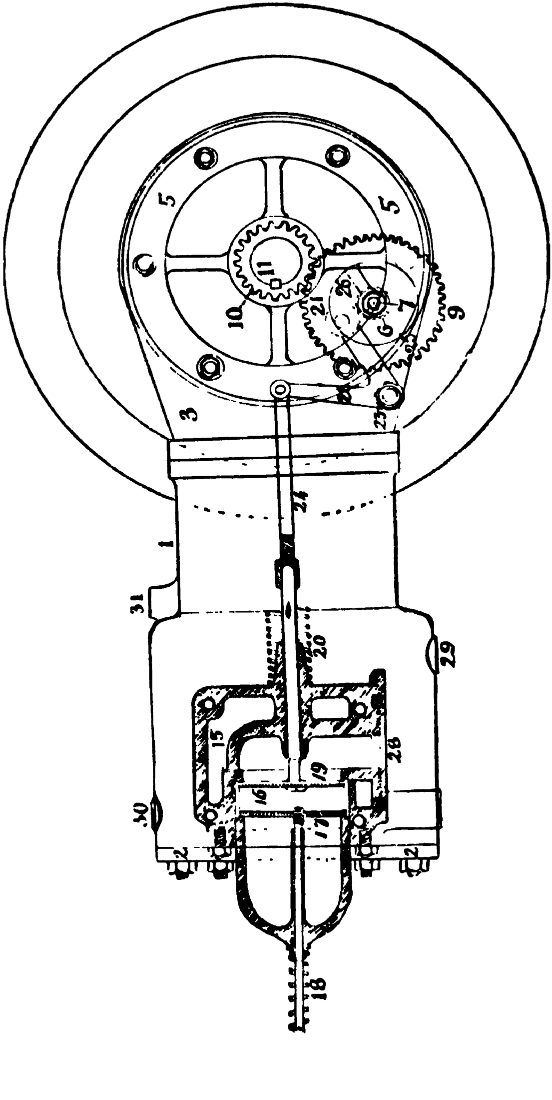


Fig. 1A.

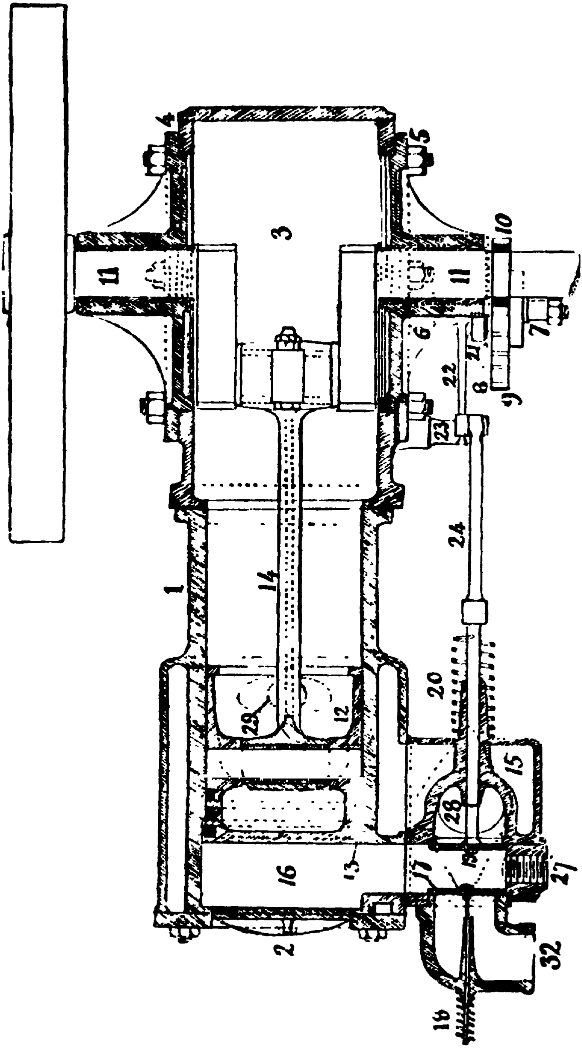


Fig. 1B.

from irksome restrictions on the road, the art of constructing and of working light, powerful engines, actuated by steam, petrol, or alcohol, has reached a higher level of perfection than perhaps in any other country.

The author is of opinion that the form of motor that will finally be adopted for all but the very smallest types of automobiles, is a small and compact steam-engine, with paraffin spray firebox, to get up the steam. As, however, these are not yet largely used, we shall direct our attention to the essential portions of the more usually employed "petrol-engine." We shall not give any detailed description of the *body* of the car, as this, of course may be varied to suit the taste and the requirements of the purchaser; and in describing the engine proper, we shall take one typical form, premising that variations may be expected in the designs of nearly every maker.

§ 2. The first essential in an automobile is that it should be able *to travel;* and this power it obtains from the motor. We therefore, present our readers, at Figs. 1*a* and 1*b*, with two illustrations of the motor, or engine proper, and at Fig. 2, with a view of the same, with its accessories, in position on the body of the car, the latter being shown in dotted lines only.

Fig. 1*a* is a vertical elevation, and 1*b* a horizontal plan, of the ordinary petrol motor; in which 1 is the cylinder, and 2 the cylinder cover, 3 the chamber containing the crank. This chamber is fitted with two covers, 4 and 5, the latter of which has on it a box 6, whence arises a stud 7, carrying a sleeve 8, whereon is formed the exhaust-valve cam. To this sleeve is keyed the gear-wheel 9, which is driven by a pinion 10, fastened to the crank-shaft 11. Since the gear-wheel 9 has twice the number of teeth as the pinion 10, it revolves at *half* the speed of the crank-shaft, thus operating the exhaust-valve at every alternate in-stroke of the piston. At 12 is the piston, which is furnished with three packing-rings 13, which cause it to make a gas-tight fit in the cylinder, and 14 is the connecting-rod, fitted with brasses at each end. The valve-box 15 is bolted to a facing, cast on the side of the cylinder, and communicating with the combustion chamber, by the port 15. The valve-box has a water-jacket, in communication with the water-jacket of the cylinder, which device keeps the valve-seatings from becoming unduly heated. At 17 is an inlet-valve, which is automatic in its action, opening by the suction of the piston, against the light spring 18. A stronger spring 20 controls the exhaust valve, 19,

which therefore resists the suction-stroke, but is lifted from its seat at every second revolution of the engine, by a cam on the sleeve 8. This cam raises the roller 21 on the bell-crank lever 22, pivoted at 23, the other end of the bell-crank lever having the push-rod 24 jointed to it. This rod serves to push up the exhaust-valve at the right times. The gear-wheel 9 is made of hard vulcanised fibre, and on its face, formed in one piece with it, is the disc 25. This serves to "time" the firing-spark. On the edge of the disc 25 is a brass segment 26, which is in metallic connection with the sleeve 8. At the extremity of the stud 7 is an insulating-plate (not shown in the illustrations), carrying a "brush" or spring which presses on the fibre disc 26. By this arrangement the circuit is completed once at every revolution, between the two extremities of the circuit of the primary of the coil, when the brush passes over the brass segment on the disc. This causes the firing-spark to be produced at the sparking-plug, which is screwed into the valve-box at 27. The petrol vapour produced in the carburettor mixed with air, which forms the explosive mixture, is led into the engine at 32. At 28 we have the aperture through which the spent, or "exhaust" gases are led away to the silencer. A lubricator, preferably of the "sight-

feed" type, is screwed into the box at 31. In order to avoid the risk of any part of the engine "binding" or "seizing," owing to having by oversight neglected to lubricate any of the smaller bearings, these should be arranged so as to lubricate themselves automatically; the studs carrying these are drilled from the insides with holes reaching to these bearings, into which holes sufficient oil is splashed by the crank during its travel. An important point to notice is that the inlet-valve 17, and the exhaust 19 should be of ample area to avoid throttling the entering charge, or setting up back-pressure during the exhaust stroke. The water-jacket, which surrounds the cylinder proper, should have no joints, but be cast in one piece with the cylinder. The entrance for the water is shown at 29, and its exit is at 30. At these points facings are cast on the cylinder, to which flanges of the water-inlet and outlet-pipes are attached by studs and nuts.

The position of the petrol-tank and of the carburettor may be varied to suit the build of the car. The carburettor which meets with most favour at present is the "spray" or pulverising type, in which a certain given controllable quantity of petrol is allowed to enter from the tank into the carburettor by a valve or faucet, where it is sucked up and broken into spray,

mixed with air and quickly vaporised by the suction of the inlet-stroke. Another useful adjunct in the motor car engine is the automatic governor, which regulates the amount of explosive mixture supplied to the cylinder. All these different devices must be so arranged as to be readily manipulated by the driver by means of levers or cranks, in order that the whole series of operations, such as admission of petrol, of air, timing of spark, application of brakes, starting, stopping, slowing or accelerating, shall be entirely under his control.

§ 3. We now pass to consider briefly the means usually adopted to transmit the power generated by the engine to the wheels of the car.

Let *a* (Fig. 2) represent the motor, and *b* the fly-wheel. On the face of this are two pulleys, *c* the larger, being the "high" speed, c^1 the smaller, the low speed pulley. *d* and *e* are belts (or in some cases chains) which convey the power to the counter-shaft pulleys *f* and f^1. On their way to these latter, these belts pass under the "jockey" pulleys *p*, p^1. This latter being under control of the spade-handle *q*, enables the driver to release the belts from their grip on the crank-shaft pulleys altogether in order to bring the low-speed or the high-speed pulleys into play, at

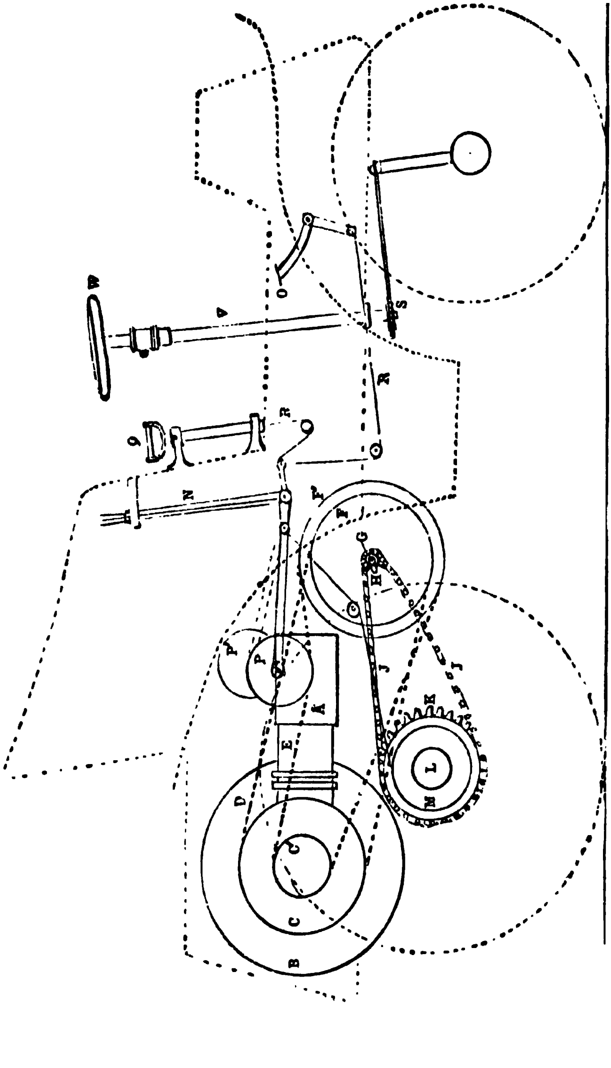


Fig. 2.

his option. *g* is the counter-shaft attached to which is the sprocket pinion *h*, with differential or balance-gear. From this runs *j*, a chain, connecting the sprocket pinion with the sprocket wheel *k*, which is keyed on the hub *l* of the road-wheel. The position of the brake-bands is shown at *m*. The brake is controlled either by the hand-lever *n*, or by the foot-brake *o*. Whichever brake is used there must be an arrangement to throw the engine out of gear with the counter-shaft at the same time, so that although the engine be running, its power shall not be transmitted to the road-wheels of the car. This is usually effected by connecting the jockey-pulley *p* to the lever *n*, and to the foot-brake *o*, as shown at *r*, in such a manner that when these are used, the jockey-pulley is raised off the belts *d* and *e*, shown at p^1. Steering is effected from the steering-post *v*, which is surmounted by a wheel at *w*. Sometimes this steering-wheel is replaced by a bar-handle; but the consensus of drivers' opinions appears to be in favour of a wheel. The bar passing down this post *v* has, at its lower extremity, a small sprocket-pinion *s*, which engages in a rack on the steering-rod that governs the direction of the front wheel or wheels.

The positions of the water-tank, of the petrol-tank,

and the carburettor are largely a matter of convenience; they are usually placed at the back of the car, or directly under the seat; in all cases easy access should be obtainable to the mechanism, by the opening of the back, or otherwise. Although in a water-cooled engine the circulation may be *natural*, yet the change of surface of the water flowing is effected with greater celerity if the water is driven by a small pump of the single-acting plunger-type, which can be actuated by an eccentric keyed on the box of the fly-wheel. This is not shown in the illustration.

Besides these essential portions, every motor car is provided with a removable cranked handle, by means of which, when the jockey-pulley is lifted away from the belts, the engine can be started by hand (without driving the road-wheels) until it has drawn the explosive mixture from the carburettor into the cylinder and fired a charge or two; after which it can be allowed to do its work automatically, and the road-wheels thrown into gear when required.

§ 4. A word or two as to the cycle of operations to be executed in starting a car may not be out of place here.

The petrol and the water-tanks must first be filled, the former with good petroleum spirit, having a Sp. G.

of 0.680 at 60° Fahr., and the latter with clean water. The ignition-coil, accumulator and attachments should then be looked to, especially as regards good and clean contacts, and the electrical condition of the accumulator. The E.M.F. of each cell should be measured by a voltmeter; it should be 2 volts per cell, and it should never be allowed to fall below 1.9 volt without recharging. The hand or foot-brake must now be put on so as to throw the jockey-pulley off the belts. Let the throttle-valve be opened as wide as possible, but leave the air-admission portion of the mixing cock quite closed. The plug must now be placed in circuit with the switch, and the sparking-gear so arranged that the spark (and consequently the ignition) shall take place immediately after the cranks have passed the inner dead centre. Now, if by means of the driving-handle the engine is caused to make a few turns, she should start; if not, it is a sign that the proportion of the air and petrol vapour in the explosive mixture are not correct; and these must be altered until the proper result is obtained. This may be done by adjusting the position of the air and the vapour-levers until the motor fires regularly. The alteration in the supplies of air and of vapour must be made carefully and gradually, as a very little makes a vast difference in

the result. It is quite worth while to try the effect of making alterations in the quantity and quality (richness in petrol vapour) of the mixture, as the experience gained by such a procedure is far more valuable than any amount of theorising. Sometimes, if the weather is very cold, or the atmosphere laden with moisture, the air is not able to take up sufficient "gas" from the petrol. In such cases it may be well, in starting, to facilitate matters by wrapping a cloth (previously plunged in boiling water and wrung out) round the carburettor. This will vaporise the petrol more readily. The cloth must then be removed, as after the first few ignitions the warm products of combustion given out by the exhaust will keep the carburettor at the right temperature, when, of course, more air can be admitted by the regulator.

When, from the above trials, the operator is satisfied that the engine proper is working satisfactorily, that the proportion of vapour and air is rightly under control, and that the ignitions are succeeding each other duly and regularly, he can take his place in the car, and having slackened the engine-speed somewhat by *retarding* the ignition, he will *gradually* bring the jockey-pulley down on the belt, by means of the starting lever, and so cause the road-wheels themselves to

enter into motion. Sudden starts or jerks must be carefully avoided. Some careless drivers will let the engine go at full speed, then suddenly pull down the lever, thus causing the car to bound off at a great rate. The car should be started slowly, remembering that the speed can be slackened by retarding the ignition, and increased by accelerating the same, care, of course, being taken to vary the quality and quantity of the explosive mixture to suit the requirements.

The following excellent hints, drawn up by J. W. Packard, of the Automobile Company, embody the chief points to be attended to and avoided in motor car driving: "Don't forget to turn on petrol and spark before attempting to start. Don't forget to turn oil on and close compression after starting. Don't try to run carriage without oil in oil-cups. Don't try to run without water in tank. Don't try to run without petrol in tank. Don't leave your car to freeze in winter. Don't jerk in your clutches; bring them up gradually. Don't change gears on a hill, until your car is nearly at a standstill.* Don't start down a hill at a rapid rate, and then jam on the brakes. Don't try to turn corners rapidly with brakes on. Don't forget

* This, of course, applies to cars in which changes of speed are effected by gear, and not by belts.

to turn off oil-cups when shutting down. Don't tighten clutches so that they drag or bite. Don't neglect to turn off petrol at night. Don't pull carburettor to pieces without carefully noticing how it is put together. Don't screw up governor contact-points too tightly. Don't tinker with adjustments of governor, or if you should, don't advance spark from centre point when pulled over by hand. Don't neglect to keep contact points clean. Don't allow any bell-hanger or cycle repair man to add 'improvements' to your car. Don't use cheap or poor lubricating oil. Don't let your engine race at any time, or run at an excessive speed when using low-speed gear. Don't leave your car *unattended* with engine running. Don't expect that all you have to do is to pull the lever. Learn to thoroughly understand the mechanism and adjustment of your machine."

§ 5. Lubrication is a very essential point in the working of a motor car. We have already pointed out how the smaller bearings are automatically lubricated by the "splashing" of the crank in its travel, supplying some oil by means of holes drilled for this purpose into the studs connected with these; and here we may mention that there should be an oil-hole in the exhaust valve stem.

The nature of the oil to be used will vary somewhat with the parts to be lubricated. As a general rule we may say use with advantage the thickest oil* that will flow to the parts. For water-cooled motors, an oil of medium viscosity, which will stand a fire test of 470° Fahr., will be found generally useful. For gear-boxes, a heavy black hydrocarbon oil, standing a fire test of 500° Fahr., will be found the most suitable. By "black" we do not mean *dirty* oil, but simply the natural dark colour of the pure oil. Many drivers use semi-solid lubricants. To this there is no objection, provided the lubricant finds its way to the spots at which lubrication is needed, as a semi-solid lubricant has the advantage that it prevents the entrance of road-dust, dirt, and grit, to the bearings. Were it not for the difficulty of application, graphite, or plumbago (not ordinary black lead), would be an ideal lubricant. As it is, in the case of a bearing or piston which has got slightly injured through want of lubricating, it is the only thing that will bring the surfaces back again into good condition. For the valve-stems and the pump, it is perhaps the only lubricant which is always satisfactory. It would appear from careful trials that the use of suitable hydrocarbon oils for lubrication

* Mineral, *i.e.*, hydrocarbon.

increases the power of a 6-h.p. engine by about $\frac{1}{8}$ h.p., besides prolonging the life of the engine itself. Castor oil is often employed on the belts and straps to increase the adhesion. The use of resin for this purpose is highly objectionable; but should necessity compel its use, to prevent injury to them the belts should be well washed in paraffin on returning home.

§ 6. In the choice of a car, the following points require careful notice. There should be as few moving parts as is consistent with obtaining the movements desired.

The machinery should be easily accessible. Water-tank, water circulation or other means of cooling should be ample. A very important point is that all parts should be interchangeable and readily supplied by the maker of the car. Lock-nuts should be of the helicoid type. The machine should be strongly built, so that repairs may limit themselves to the replacement of worn or damaged parts. With regard to the engine proper, the vertical type seems to be giving the best results, although up to the present most cars are fitted with the horizontal engine. Excessive speed must be avoided; anything that requires an engine speed of over 800, or at most 1,000 revolutions per minute, is to be shunned. Ribs, in the cylinder cover,

not only strengthen the same, but help to dissipate heat by radiation. The exhaust silencer should be as noiseless as possible. The silencer can often be made more efficient by wrapping with ¼ in. asbestos sheet, and putting a lining of the same round each compartment, care being, of course, taken not to block the air holes. The counter-shaft pulley may be of cast iron.

Although not shown in our illustrations many modern cars have 3-speed gears. Others have worm drive and no chains. Most of the belt-driven cars require two motions to be made to put brake on, one to shift the belt from the driving pulley to the loose pulley, and the other to apply the brake. There are however, some excellent machines that perform both these operations with one movement of the lever, which, other things being equal, are preferable. A governor, which automatically reduces the speed of engine when the car is stopped, is also a great convenience. If too much complication is not introduced in effecting the result, lubrication, which automatically stops the supply of oil when the engine comes to a standstill, is desirable. With regard to the steering-post, the wheel is certainly more generally convenient than the bar-lever; and a pinion running between two racks is preferable to the chain for conveying the

movement to the front wheels. Wherever pinions are used, as for instance, on the counter-shaft, they should be large, both to avoid noise and rapid wear of chain.

The amount of petrol used will naturally vary with the work put upon the engine; but to give a rough idea of fair average consumption, we may say that a 3-h.p. engine should not consume more than 4 gallons of petrol in a four-hour run of 80 miles.

SECTION II.

IGNITION DEVICES FOR GAS AND PETROL MOTORS.

§ 1. Ever since the advent of the gas-engine, and of its congener, the "oil-engine," much ingenuity has been displayed in the construction of suitable contrivances for igniting the explosive mixture. It will be evident, on the slightest consideration, that the conditions to be fulfilled will necessarily vary with the varying circumstances in which the engine is to be employed, and that an igniter which would be eminently suitable for a stationary gas-engine, might be quite inapplicable to a portable petrol motor forming

part of an automobile car, or of a motor-driven bicycle. As so much interest has of late been evinced in this subject, we make no apology for presenting the following epitome of the more important devices in use for this purpose, with a few remarks as to their fitness or unsuitability for certain particular requirements.

§ 2. In the very earliest commercially successful gas-engine, that of M. Lenoir (1860), the means adopted for firing the explosive mixture was an electric spark. As in this engine no attempt was made to secure compression of the gaseous mixture, no particular care was taken to *time* the spark. "As the piston advances it draws in an explosive mixture of gas and air. About mid-stroke this is ignited by an electric spark."

In the Otto and Langen engine (1867), in which also there was no compression, the ignition was effected by a small gas flame, to which the gaseous mixture gained access at the desired moment through the action of a special slide-valve, which opened and closed a port-hole facing the gas flame. In the Otto engine of 1876 *compression* was adopted, and the compressed mixture was fired just when the forward stroke was about to begin, by means of a slide-valve

alternately uncovering and covering a hole facing a small gas flame. In the "Priestman" petroleum engine, electric ignition, in the shape of sparks generated by an induction coil, was the means first adopted; the slide-valve being the same as in the Otto.

In more recent forms of oil-engines the ignition is effected by a flame produced by a blow-through oil lamp, of the "Ætna" or "Primus" type. This lamp itself requires frequent attention to keep up the supply of vaporised oil on which its own flame depends. For all stationary work no form of ignition is perhaps so satisfactory as that adopted by Crossley Bros., in which a tube, either of porcelain or of a suitable metal, is kept nearly white-hot by a Bunsen flame playing in its interior. Neither tube nor direct flame ignition lends itself readily to small petrol motors, such as are usually adopted in cars, tricycles and bicycles. For these, electric ignition presents many advantages.

§ 3. The means employed for igniting by electricity are various:—Firstly, maintaining a thin platinum wire (placed close to the slide-valve) in a state of incandescence by the current from a battery. Secondly, producing, by the aid of a coil and battery, a continuous stream of sparks before the slide-valve. Thirdly,

the production with the coil and battery of sparks between the platinum points of an igniter, which is inserted in the explosion chamber of the engine, the time at which these sparks take place being controlled by a cam, or other device that makes (or breaks) the circuit at the required instant. Fourthly, the production of sparks directly from a magneto-machine, or from a dynamo driven by the motor itself. Fifthly, producing sparks from a composite machine called a "dynamo-coil," in which the field-magnet and *its* winding form at the same time the core and primary of the sparking coil, which therefore admits of accurate timing of the spark, by interrupting the circuit in the primary. Of these, the first may be dismissed from further consideration, since it is very difficult to maintain a platinum wire at the point of incandescence by the battery current, without either fusing it, if the current exceeds the normal, or allowing it to become too cool if the current falls below that point. Besides this defect, the platinum wire is very apt to become encrusted with unburnt carbon derived from the gas. The fourth method is open to the objection that efficient sparks are produced by the magneto (or dynamo) only when the speed at which it is driven reaches a certain point; and, moreover, that when that speed is

increased, there is considerable risk of breaking down the insulation of the generator. These objections have not much weight when the engine is stationary, running at a practically constant speed; but they become serious in cases of tramcars, motor cars, or any other vehicles in which the speed is liable to sudden variations. We are, therefore, driven to the conclusion that coil ignition in some form or other is the best for general purposes. (It may be pointed out here that even in the case of stationary engines electric ignition is superior to any form of flame or tube, as it economises gas or vapour.)

§ 4. Whatever form of coil be adopted (with the sole exception of the dynamo coil) a battery must be employed in conjunction with it, to supply the current necessary to cause it to produce sparks. Now, it is just at the battery that all the troubles begin. In stationary engines it is a nuisance to have to replace dry cells, or to dismount and remount primary cells of any kind. The former quickly fail to give sufficient current, and must be replaced; the latter more gradually, but just as surely, lose power, and must be renovated. The only battery that can be depended upon to give a sufficiently equable current for any length of time is an accumulator of fairly large ampère-

hour capacity. This is really the best, we might say the only satisfactory, source of current which can be used for working the coil. But the accumulator must be recharged. This is not a serious matter in the case of stationary engines, where access can be had to a charging station, or where a portion of the power of the engine can be deviated from the general work to drive a dynamo from which a spare accumulator can be charged. But when we come to deal with accumulators to be fitted into petrol-engined launches, petrol motor cars, motor tricycles or bicycles, in which the success of a trip depends on the condition of the accumulators, and in which it is frequently impossible to have recourse to a charging station, some means of maintaining the accumulator charged to a working point becomes a matter of the highest importance.

We can now pass to the consideration of the requirements in a dynamo suitable for stationary gas or petroleum engines. Circumstances only can decide whether it will be more convenient to allow a portion of the spare power of the engine to be employed continuously for the purpose of keeping the accumulators charged, or whether a certain time in each day shall be set aside to attain this end. In the former case, the dynamo must be fitted with some automatic device

(called a "cut-in and cut-out") which shall break the circuit between the dynamo and the accumulator whenever the dynamo gives less than the required charging voltage, and shall complete the circuit when the voltage reaches the necessary point. The automatic cut-in and cut-out is an absolute necessity in all cases in which the engine is subjected to variations in speed, due to different loads being put on her. In the case of a certain time each day being set aside solely for charging, the employment of the cut-out, though convenient, is not so imperative, since the dynamo attendant, by keeping his eye on the voltmeter, can immediately switch out the dynamo if he finds the voltage falls below the necessary 2.5 volt per cell. It is needless to remark here that whatever type of dynamo be employed, it must be *shunt* wound, or, if *compound*, the shunt coils alone must be employed. *Series* wound machines and *alternators* are of no use for this purpose. The particular type of machine is of no great moment; ring and drum armatures are the best, but the outward form, all other things being equal, is of some importance. In large establishments in which the dynamo can be kept away from the general workshops, any good dynamo, whether open or in-closed, is admissible, and in fact the open type pre-

sents some advantage in presenting easy access to the brushes, etc., for regulation. But in all cases in which dirt or dust is present in the dynamo-room, the machine should be of the inclosed type. We do not mean by this that the dynamo should simply be inclosed by a covering, whether of wood or of metal; but that its construction should be such that the entirety of its working parts (with the exception of shaft and driving pulley) should be inclosed in *iron*, this iron forming an active portion of its field-magnet system. The first real iron-clad dynamo was devised by Mr. Tighe in 1882. In this a single wound pole arose from the centre of an iron cylinder, the top of the cylinder being dome-shaped and forming the other pole of the dynamo, the armature playing between the central pole-piece and the dome. A very similar pattern, excepting that the cylinder terminated in a circular cap, was designed by Mordey for the Brush Company. This form has been largely adopted by more recent makers as being at once efficient, compact, and having its working parts fully protected by the massive outer iron cylinder.

§ 5. The exterior form of the inclosed dynamo is evidently not of so much moment as its adaptability to the varying speeds to which it may be subjected. In

the earlier types of inclosed dynamos, dating, as we have seen, from about 1882, applied, as they were, principally to keeping up the charge in accumulators for stationary engines, neither the question of weight nor the capability of self-adaptation to great and sudden variations in speed were of paramount importance. But, with the advent of the motor car, the electric cab, the motor bicycle, and motor tricycle, it became imperative that the inclosed dynamo should be at once light, compact, efficient, and capable of being driven at greatly different rates, without either injuring the accumulators which it is destined to charge or risking the breakdown of its own insulation. It is difficult to unite in one machine all these requirements. If the dynamo be very small, and contain but little iron, it must be driven at a high speed, and must be wound with fine wire, and this fine wire presents resistance to the current, which results in *heating*. To be efficient, the dynamo must have a certain amount of iron in it, duly proportioned to the wire on the armature and field-magnet system. This means that all the *metal* parts of the inclosed dynamo should, as far as possible, be of iron, and that this iron should form an active portion of the field magnet and armature. (This, of course, does not apply to the armature conductors, nor

to the F.M. coils, which are, in all modern machines, of copper.)

By carefully proportioning the machine it is possible to construct an inclosed dynamo, weighing about 6 lb. to 8 lb., which shall be well able to charge the four-volt accumulators usually employed in motor cars, etc. If the machine take the form of an upright cylinder, or even a square box, with, of course, the contained upright field-magnet core and armature, it is possible to construct it so that no electrically useless metal is used except that for the bearings, the brushes, and the lubricator. But this leaves untouched the question of *speed variation.* As far as injury to the accumulator is concerned, this difficulty can be got over in several ways, such as, for instance, a hand-governed resistance, more and more of which can be switched in when and as the speed increases. Or an automatic cut-in and cut-out can be adopted, which shall complete the circuit when the speed attains a certain point, and break it again if it overpasses a given range, to remake it when the speed falls to within the "safe charging limit," etc. But an automatic cut-out is rather delicate in its action, and the jolting and trembling of the motor car is not conducive to its satisfactory behaviour. Neither of the

above-mentioned devices, nor indeed anything external to the dynamo, can prevent injury to this latter if the speed be greatly in excess of the normal. But it is possible to control the output of the dynamo by altering the strength of its magnetic field, and this can be done automatically by cutting out more and more of the field-magnet coils as the speed increases, or, what amounts to the same thing, automatically inserting a dead resistance in the field-magnet circuit when this occurs.

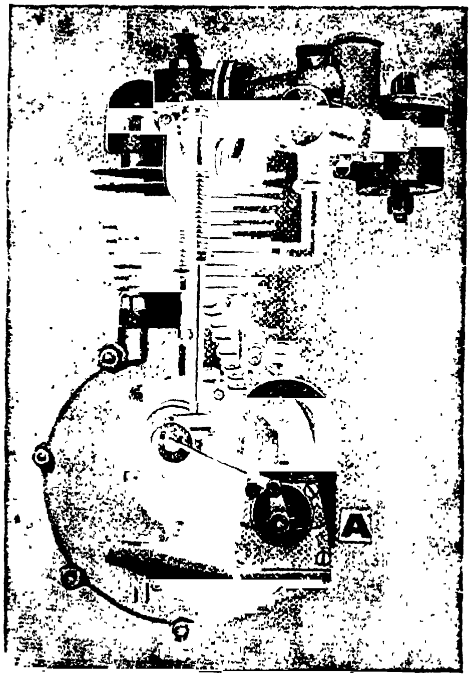
§ 6. Having pointed out the requirements for electric ignition, we will proceed to describe briefly the more successful appliances that have been employed for the purpose. The first device (apart from the coil) which was used was a modification of Breguet's "torpedo exploder." In this a finely-wound horseshoe-shaped armature was hinged in front of the poles of a powerful compound permanent magnet in such a manner that by striking a lever attached to the armature this latter was suddenly removed from its proximity to the poles of the said magnet; returning after the stroke by the action of a spring in connection with the lever. This sudden motion of the armature, by cutting the magnet's lines of force, set up a current of high E.M.F. in the coils of the armature, which current

was led by suitable wire to the slide-valve opening, or to the ignition plug of the engine, when it produced a spark. The lever was actuated by a cam on the engine itself.

A more modern application of the magneto machine to the purpose of ignition is that known as the "Simms-Bosch." In this we have three permanent horseshoe magnets, bestriding the pole-pieces, in which is bored out a cylindrical tunnel to take the armature. The armature itself is a fixture. It is wound with wire suitable to produce the required spark, which is obtained, not by causing the armature to rotate or to oscillate so as to cut lines of force, but by imparting a reciprocating movement to a soft iron envelope, which lies between the armature and the magnets, and which, by virtue of this movement, uncovers the iron portion of the armature, giving rise to a momentary electric current, which evidences itself in the form of a spark at the ignition-plug. As in the former case, the motion is imparted by a cam and lever on the engine. The Simms-Bosch magneto admits of very accurate timing, and is a marked step in advance upon the older form, in which the armature moved.

Fig. 3 represents the Simms-Bosch magneto igniter in position on the Simms motor. The weight of these

appliances varies with the purpose and speed for which they are intended. Thus, for stationary engines, running at not less than 60 R.P.M., the weight is 28 lb.; for automobiles, to run at not less than 300



R.P.M., 20 lb.; for very light work, cycles, etc., at a speed of not less than 300 R.P.M., the weight is

§ 7. A very neat and efficient igniter was brought out in 1899 by the Elbridge Electrical Manufacturing Co., U.S.A. Two sizes were put on the market; the larger, mark "S," being a circular carcass, two-pole drum armature dynamo, series wound; size 10 in. high and about 10 in. from end to end of shaft. The weight is 47 lb. Owing to the special construction and winding of this machine, no "sparking" or "in-

Fig. 4.

duction" coil is needed, a bright spark being always obtained at the breaking of the circuit. This dynamo will not lose its magnetism when short-circuited, and will always increase its output at the moment when the spark is obtained. The bearings are extra long, and are lined with Babbitt metal. The lubrication is effected by "wick" oilers, the reservoirs holding enough oil for a week's run. The commutator is constructed of tempered copper, and is very wide. The

brushes are of carbon of ample carrying capacity, and no harm is done if the dynamo be accidentally run backwards. The normal speed of this machine is 1,400 R.P.M. As all the working parts are included in the frame of the machine, they are well protected from external injury. Fig. 4 gives a good general idea of the larger Elbridge "sparking dynamo."

The small size, "R," is intended specially for small

Fig. 5.

launches, automobiles, and where the larger machine would be too heavy. The general principles of construction are the same; but the dynamo itself is of the "inclosed" type, so as to protect the working parts from dust and dirt. The weight is only 14 lb., which is less than that of an ordinary coil and accumulator; the height is only 6½ in., and the extreme length 9¾ in. The normal speed for driving to give good sparks is

1,600 R.P.M. Special attention is given to all bearings, so that the machine can be run continuously for a long period without showing appreciable wear. The brushes are of carbon and copper combined, thus insuring good conductivity and sparklessness. The bearings are made of Holmes's "fibre-graphite" composition, and require no oil whatever. Fig. 5 shows the machine with its covers opened back; Fig. 6, the

Fig. 6.

same dynamo, with the covers closed as in actual work. Owing to the nature of the circuit, these Elbridge sparking dynamos require the employment of a "wiping" or dotting contact at the point of spark production. They are not adapted for use with the ordinary sparking plug, in which there is a gap between two platinum points.

§ 8. In the "dynamo-coil" made by S. Bottone and

Son, the problem of obtaining the steady and certain flow of "hot" sparks, as from an induction coil, without the annoyance, weight, and uncertainty of batteries or accumulators, has been successfully grappled with.

The dynamo coil, as its name implies, is a hybrid between a dynamo and an induction coil. Imagine an ordinary series-wound dynamo of such size and shape as to fit easily into the space generally allotted to the sparking-coil in a motor car. It is convenient, though by no means indispensable, that there should be only one field-magnet core, and this built of the softest iron wire possible. Around this are wound the series coils of the dynamo proper. So far, there is practically no difference between this and an ordinary series-wound dynamo. Over the series coils, but quite independent of them, and well insulated, are wound several thousand turns of fine wire, precisely similar to the secondary of an induction coil, the two extremities of which are connected to terminals (or other electrodes) that serve to convey the induced current to any point at which it is desired to produce the spark. Fig. 7, which is a partially sectional view of one of the older types of "dynamo-coil," gives an idea of the general disposition of the parts, but does not indicate the proper connection to firing plug, the devices by which

the exact timing of the spark is effected, nor the means adopted to enable the dynamo coil to adapt itself to variations in the speed of the engine. In this figure A is a soft iron wire bundle, which serves at once as the core of the coil, and as the field-magnet of the dynamo; F F show the position of the coarse-wire

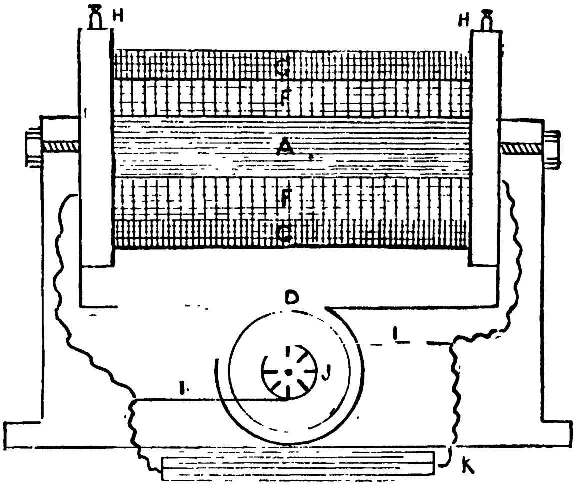


Fig. 7.

winding, which renders the machine at once an efficient series-wound dynamo, and imparts magnetism to the core as in an induction coil. Thence the wire is led to the brushes I I, whence the current generated by the armature D is picked up. J is the commutator, G G are the secondary coils, the terminations of which

are brought out at H H. (In the modern type of dynamo coil *only one* wire is required for connection to firing plug). A condenser K is in circuit with the primary winding. It will be evident that as long as the potential of the current flowing round the core A remains the same, no current will be generated in G G;

Fig. 8.

but if any interruption be made in the primary circuit a heavy flash will occur between the points across the terminations H H. No vibrating contact-breaker is required; a simple plunger, which is affixed as a kind of stud to one side of the dynamo-coil base, and which is actuated by the "half-speed cam" of the motor car, etc., serves to break contact, and this act of breaking

contact can be timed with the greatest nicety, so as to insure firing at the most opportune moment. Figs. 8 and 9 are side and back elevations of the perfected forms of the dynamo coil. The base is an aluminium case, containing the condenser and fitted with the plunger P, and a bolting-down lug on each side. This bears upon it the dynamo carcass, surmounted in its turn by the "coil" portion. To the left of Fig. 8 are

Fig. 9.

seen the bearing, the driving gear, and the lubricator, the right hand showing the commutator and brush end of the machine. The only wire necessary for connection to firing plug is seen attached to the plug at the top of the coil. Fig. 9 is the back elevation of the same machine, showing more distinctly the contour of the dynamo coil and of the driving gear.

These dynamo coils can be made to give sparks of any desired length and frequency, from ¼ in. up to

1 in. and more, in air. They are at once compact, light, and strong, absolutely trustworthy and unfailing in action, and as they do not depend on permanent magnets for the production of current, they do not grow weaker when subjected to the vibration of the car. They weigh but little as compared to coil and accumulators or batteries, and their, comparatively

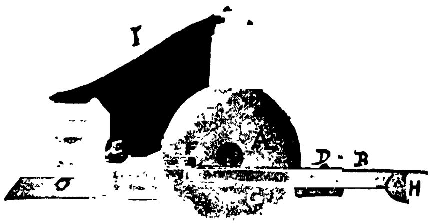


Fig. 10.

speaking, small size enables them to be fitted in confined spaces. The overall dimensions of the usual size is 8 in. by 8 in. by 7 in., and its weight is 12 lb. Fig. 10 shows the means usually adopted in order that the motorist may be able to control the speed of rotation of the dynamo-coil armature, whatever may be the speed at which his engine is itself running. The flywheel of the engine is faced with any smooth disc, as shown

at A. Across this disc lies a light shaft B B, by means of which motion can be imparted from the flywheel to the gear on the dynamo coil at C. This shaft is supported on bearings at D and at E. A portion of this shaft between the centre of the disc and the edge nearer the dynamo coil, is fitted with a key, along which can slide a friction pulley, F, which, though it can be slid along the shaft, causes the shaft to rotate in obedience to the impulse of the disc. A sliding guide bar, G, with its handle H, completes the equipment. It will be clear, on inspection of this figure, that when the pulley is drawn towards the centre of the disc, the rotation speed of the armature will be *slow*, even if the engine be running fast; whereas, if the pulley be set near the circumference of the disc, the speed will be very high, as is required on starting the motor. I shows the position of the only wire needed as connection between the dynamo coil and the ignition plug.

§ 9. There can be little doubt that the dynamo coil is at once one of the most efficient, the lightest, and most satisfactory means of securing the ignition of gaseous mixtures. But there are many engines, both stationary and mobile, which are fitted with coils; and many of our readers may have occasion to use, to repair, or even to make coils suitable for this purpose;

hence a general description, followed by a few hints as to construction, will not be out of place here.

For the purpose under consideration, coils may be divided into two classes, viz., 1, those wound with one continuous length of wire; 2, those in which there are two separate windings, one of a comparatively coarse wire, called "the primary," and another of finer wire known as "the secondary." Those of the first class, or "simple primary," can only be employed where a *wiping* contact is admissible, and therefore we shall dismiss them with a very brief notice. Coils of the second class can be subdivided into those which have a vibrating contact-breaker as an essential portion of the coil, and those in which the make and break of the contact is effected by some mechanical device, actuated by a cam on the engine itself.

§10. The principle of action of the coil is very simple, and although during the work of a coil there are concomitant actions going on which somewhat complicate matters, it will not be necessary for our purpose to go very deeply into these points.

The first fact that claims our attention is, that if we take a length of wire and coil it into a helix, a momentary current sent through the helix sets up two actions. (1) On *making* contact with source of current, a

momentary current in the *opposite* direction to the main current is set up in the wire. But as this current is only transient, and weaker than the main current, its presence can only be detected by the momentary weakening of the main current. (2) On *breaking* contact with the source of current, another wave of current is set up in the helix, this time in the *same* direction as that of the main current.

It must be particularly noted that these effects are transient, and produced at the instants of "making" and "breaking" contact only; and are not in evidence *while* the main current is flowing. The currents thus set up were originally called "extra" currents, but are now known by the more appropriate one of "self-induction currents." Each turn of the helix has a given E.M.F. induced in it, so that the E.M.F. is proportional to the number of turns in the helix, multiplied by the original E.M.F.; but since we cannot *produce* energy, but only change its form, we find that the *volume* of current (the ampères) is diminished in like ratio. So that if we supply a current of 1 ampère at 1 volt pressure to a coil consisting of 1,000 turns of wire, we may expect, when breaking circuit, to get a momentary current of $\frac{1}{1000}$ of an ampère, at 1,000 volts pressure, less, of course, a certain

amount of loss due to the conversion of part of the energy into heat, and dissipation of the magnetic fields, etc. The second point that demands attention is, that if two distinct wires lie side by side, but not in electrical contact, and momentary contact be made with any source of current and one of the wires, a similar transient current will be set up in the adjacent wire; but in the opposite direction to that of the inducing current. Owing to the damping effect of the "make" self-induced current in the first wire, the "make" induced current in the second wire is not very strong. On *breaking* contact between the source of current and the first, or "primary" wire, a second momentary current is set up in the second (or "secondary") wire. But this is now in the *same* direction as the originally "primary" current was, and since it is not checked by any counter-effect from the primary, the resulting "break-contact" current is much more powerful than the corresponding "make-contact" current was.

It will be evident that if we coil the primary wire into the shape of a tight helix, and surround this with a large number of convolutions of secondary wire, we can exalt the E.M.F. (lowering in like degree the volume of current in ampères) to almost any desired

extent dependent on the ratio between the number of turns on primary and secondary respectively. If, instead of winding the primary wire into a coil without any core, we wind it upon a core of *soft iron*, as this latter will concentrate the magnetic field, instead of allowing it to stray, we shall largely increase the induction effect, both on primary and secondary windings. We are now in a position to understand what is essential to the production of a good sparking coil, whether "simple primary" or "secondary."

In the first case we require a soft iron core, to concentrate the magnetic fluid set up, overwound with a sufficient number of turns of insulated wire to raise the E.M.F. set up by the battery to a sufficient degree to enable it to produce a spark of the length desired; and, lastly, some device for making and breaking contact between the battery and the primary at the time and the place where the spark is required. In the second case, besides the iron core, the primary, and the contact breaker, we require some means of taking up the self-induced current, which we cannot in this case utilise, and which is actually detrimental to the efficient working of the secondary. Over this we must have a sufficient number of turns of a finer secondary wire, entirely separate from the primary, to set

up an induced E.M.F. sufficiently high to produce a spark of the desired length. For this case also we must have a means of making and breaking contact with the battery, accumulator, or other source of current. This second form of coil differs, however, from the first, inasmuch as the contact-breaking arrangement is quite independent of the *place* at which the spark is produced, so that the contact need not be made and broken at the spot where the ignition is required.

§ 11. The following details as to dimensions, gauge of wire, and general mode of construction, may be useful to those desirous of building a "primary" coil, suitable for gas or petrol-vapour ignition. We repeat here that this type of coil is suitable only for those cases in which the act of "contact-breaking" can be effected at the spot where ignition is desired.

A couple of hard-wood heads (oak or beech), 4 in. square by 1 in. thick, should be planed up, and soaked for some time in melted paraffin wax. Through the centre of these a hole ¾ in. in diameter must be put. A bundle of perfectly straight soft iron wire, No. 22 B.W.G. (carefully annealed in the fire, and allowed to cool slowly in the ashes), is now to be made up into a cylindrical core, 12 in. long, ¾ in. diameter. The

neatest way to do this is to get a couple of curtain rings ¾ in. inside diameter, and having made up a bundle of wires nearly the desired size, place a ring on each end, at about ½ in. from each extremity, then cautiously push in more wires until the whole is firm and solid.

A piece of 1 in. wide tape is now taken and wrapped spirally from end to end, as tightly as ever it can be drawn, and the termination stitched down to the layer below, so as to prevent uncoiling. Any excess of tape can now be cut off and the rings removed. Over the completed core it will be advisable to roll and paste down one turn of stout brown paper, which should be rolled with a flat board on a flat table so as to cause it to lie tightly, flatly and smoothly. This being done, the core is allowed to dry thoroughly, upon which it should be allowed to simmer in hot melted paraffin wax until no more bubbles appear; then reared up on end to drain and cool. When cold, the core is fitted and glued into the holes in the wooden heads (these being slightly enlarged by rubbing round with a circular stick covered with sandpaper, if necessary). The ends of the core should come up flush with the outside faces of the heads, and in order to insure a perfectly rigid fit, it may be advisable to drive two or

three short lengths of the No. 22 iron wire into the centre of the core at each end, so as to swell it at three points. Care, of course, must be taken that the heads stand perfectly square and parallel to each other. A small hole (about $\frac{1}{16}$ in. diameter) to allow of the passage of No. 18 double cotton-covered copper wire is now drilled through one of the heads, close to, but not touching, the core. Through this hole is pushed from the *inside* about 3 in. of a 4 lb. hank of No. 18 double cotton-covered copper wire, and the core wound evenly from end to end. As this wire is pliable, and not too fine to handle, the winding may be done by hand with perfect ease; but it may be done more quickly if the core be set up between centres and rotated while the wire is being gently pulled. Care must be taken to wind the wire on evenly and closely, so as to leave no spaces between the rows.

When one layer has been laid on, the wire should be fastened back, or held by an assistant, so that it should not uncoil, and the layer then basted with hot melted paraffin wax, any excess being melted off by passing over the surface of the layer with a strip of hoop iron, about ¾ in. wide, made sufficiently hot to melt the paraffin wax, but not to burn it.

Winding always in the same direction, but returning towards the head at which the start was made, a second layer of wire is now put on, with all the precautions indicated above. This is also paraffined, and the winding and basting continued in like manner until the whole of the wire has been wound on, which will take about 17 layers. Care should be taken to terminate with an odd number of layers, so as to get the finishing end of the wire close to the opposite head of the coil from which the start was made. A hole is now made in the head at this point in a line with the other hole, the wire end pulled through to the outside, and cut off at a distance of about 3 in. from the face of this head.

A few sheets of demy paper are now prepared by dipping in melted paraffin wax and hanging up to drain. When cold, these are cut into strips about 18 in. long and of sufficient width to lie exactly between the heads of the coil. About six of these strips are now bound, one after the other, tightly round the last layer of the wire and fastened down by warming the last edge with the hot hoop-iron strip, so as to cause the paraffin to melt and stick. Over this as a finish, one turn of sheet ebonite ($\frac{1}{64}$ in. thick) should be rolled round, little holes being made in the oppos-

ing edges with a hot wire, and then stitched together with a suitable length of strong black silk twist. Two holes, to take the screw-shanks of two terminals, are now drilled, one in the centre of the edge of each of the heads, nearest the projecting wire ends. The wires are straightened out, bared of their covering, and cleaned bright with a bit of emery cloth, looped once round the stem of the corresponding terminal, which is then screwed up tight. The excess of wire is now cut off flush with the terminal.

The coil may now be tested by connecting one terminal to a wire from one pole of a 2-volt accumulator, or a couple of large dry cells coupled in series; then quickly making and breaking contact with the other terminal by means of a second wire proceeding from the other pole of the accumulator. A bright and heavy flash should appear each time contact is broken. Care should be taken, in making these trials, not to leave the battery connected with the coil, because, as the resistance of the wire on it is but low (about 2 ohms), the battery will soon be run down.

§ 12. It will be readily understood that the form of such a coil may be somewhat varied to suit the exigencies of space, convenience of stowage, etc. The heads may be round instead of square, and the coil

may be made only 6 in. long instead of 12 in., the winding being effected with No. 20 wire instead of No. 18, provided about 2,500 turns be got on the core. To work such a coil, any cell capable of sending about 2 ampères through will cause it to give a good heavy flash, capable of firing the gaseous mixture. The best cell to employ for the purpose is undoubtedly a 4-volt accumulator, of about 14 ampère-hour capacity.

We now proceed to show the means which may be adopted to effect the firing of the gaseous mixture at the right time and place when a "primary" coil, such as described in our last few sections, is employed. The simplest means which may be used in stationary oil or gas engines consists in connecting up the body of the cylinder to the negative wire of the coil, and arranging a platinum-faced L-shaped brass piece, pivoted at the bend, which wipes across a wire or a nipple situated just in front of a hole in the combustion chamber. This L-piece is in circuit with the battery and the other wire of the coil, and is caused to "wipe" across the nipple by means of a cam connected to any rotating portion of the engine. To bring this L-piece into the "off" position after having received the push from the cam, it is furnished with a counter-spring. Of course, the cam must be set in

such a position as to insure the spark being produced at the right instant.

Another simple means consists in inserting a porcelain plug in the ignition-chamber of the cylinder, this plug bearing up its centre two wires, insulated from each other and projecting into the cylinder, one shorter wire terminating in a platinum stud, and the other bearing a platinum-tipped spring. This plug is inserted in the cylinder in such a position that, when the piston has reached the point of greatest compression, it pushes the platinum-tipped spring against the platinum stud, thus completing the circuit between the battery and coil, wires from which are connected to the externally-protruding wires (or, better, terminals) of the porcelain plug. Directly the piston has passed the dead-point, and begins to travel outwardly, contact is broken between the platinum-tipped spring. Hence a spark is produced in the combustion-chamber, and the charge is fired.

The great defect in these two modes of firing is the difficulty of timing the spark while the engine is in motion. Now this power of timing the spark (and, consequently, the explosion) is a matter of the highest importance, especially for motor car and cycle work, in which the speed and power may want to be sud-

denly and largely varied. A moment's examination of the annexed figures will show this.

Let us suppose, as illustrated in Fig. 11, that the explosions were made to take place, in starting the engine, when the piston is at the beginning of its stroke, with its crank quite straight, or at the "dead-point." It is evident that the piston could not move:

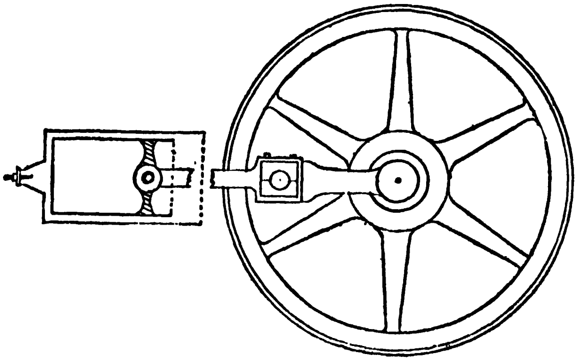


Fig. 11.

consequently, the explosion would only strain the cylinder, and do nothing else. Therefore it is essential, in *starting* the engine, that the explosion should not take place until the piston has passed the dead-point; but the further the piston has travelled before ignition is effected, the less the compression, and consequently the less the power exerted. Once the engine is well started, the momentum of the flywheel

will carry the piston over the dead-point, even if the ignition takes place at the instant of greatest com pression, which is the time of greatest efficiency.

§ 13. One simple means of effecting the change of "timing" the spark, when a primary coil is used to effect ignition, is shown at Fig. 12. Let A be a handle or lever, capable of being set at any point by "notching" or by screw and nut. This plays in any con-

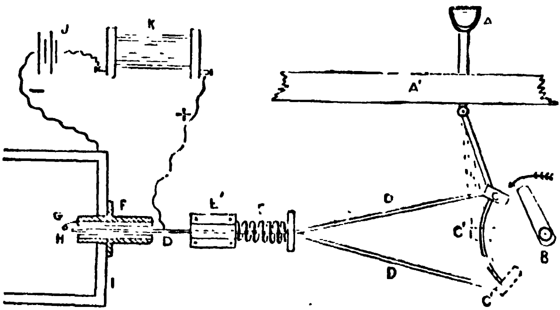


Fig. 12.

venient portion of the frame of the car, cycle, or engine A′. The lower extremity of this handle-bar or lever has a hinged rod extension, which engages in a tooth C, which can be run along the quadrant of the trapezoidal plunger D D D D. This tooth is struck by the half-speed cam, B, once in each revolution, at the same time driving the trapeze rod backwards (against the pressure of the spring E) and causing the platinum

boss H, of the plunger D, to wipe against the platinum tip G of the ignition-plug F. Directly the spring returns the rod, a spark is produced between G and H, owing to the " break " which then occurs in the circuit between the battery J and the coil K, at the point G H. (The reader will observe for the sake of clearness we have placed the half-speed cam separate from the engine and cylinder; whereas, in practice, it would form part and parcel thereof.) When the tooth is in the position depicted at C, the firing would take place *before* the piston has reached the end of its inward stroke, just before the full compression has taken place. If, by lowering the lever A, the tooth were set as shown at C′, firing would occur at the instant when the piston is at the point of greatest compression, while, if by yet further lowering the lever A, the tooth or lug were placed in the position indicated by the dotted figure at C″, the firing would be retarded until the piston had travelled somewhat on its outward stroke, and so on for any intermediate positions.

It is advisable that the " live," +, or positive wire of the coil should be connected to the platinum-tipped rod D, which must be insulated. This is effected by lining the interior of the ignition-plug with porcelain, and the extension of the rod D, where it passes into the

guide E′, should also be insulated. The negative or —pole of the battery J may be "earthed," that is to say, connected to any part of the engine frame.

§ 14. It will be evident, from a moment's examination of the figure, that this arrangement admits of considerable variation, to suit particular requirements, such as firing the charge from the *outside* of the cylinder (as is often required in stationary engines). To effect this, an insulated V-shaped brass lever pivoted at its apex, and pushed on one side by a suitable spring, rubs against a springy wire or plate, both being affixed over against the hole in the cylinder where the explosion is desired. When the extension of the trapeze D is pushed backward by the impact of the cam B striking the tooth C, it causes the upper limb of the lever to slide off the wire or plate, thus breaking the circuit between battery and coil at the point, when a spark is produced, and explosion of the gaseous mixture results.

As the contact is a rubbing or "wiping" one, the surfaces remain bright by friction; so that they need not, in this or other rubbing contacts, be tipped or faced with platinum. After contact has been broken, and the cam B has passed over the tooth C, the counter-spring pressing on the V-shaped lever reasserts its

power, and slides the lever on the wire or against the plate, again making contact. Connection must be made between the negative end of the battery and engine on the one hand, and between the positive end of coil and V-piece on the other.

§ 15. We can now pass to the consideration of the "secondary" coil, which is the one usually employed for the petrol-engine ignition, as it lends itself readily to the solution of the problem of producing the spark at any part of the circuit, independently of the point at which the battery contact is broken.

As the satisfactory working of petrol motors is largely dependent on the efficiency of the coil, we shall enter rather fully into the principles which govern its action, and follow on by giving such constructional details as will enable the reader to make a serviceable coil if desired, or to localise the faults and repair the same in a coil which may not be doing its proper work.

§ 16. The "secondary," "sparking," or "Ruhmkorff" coil consists in six essential portions—viz., (*a*) the iron bundle or core, (*b*) the primary winding, (*c*) the secondary winding, (*d*) the contact breaker, (*e*) the condenser, (*f*) the insulation.

At Fig. 13 we give an illustration of a typical coil in which *all* these parts are shown. As in the various

makes of coils these parts may be modified in form or in position, we have lettered these portions, and shall make use of the same lettering in the following illustrations to indicate the same parts, whatever may be the changes introduced, either in form or in position.

The iron core *a* consists in a cylindrical bundle of

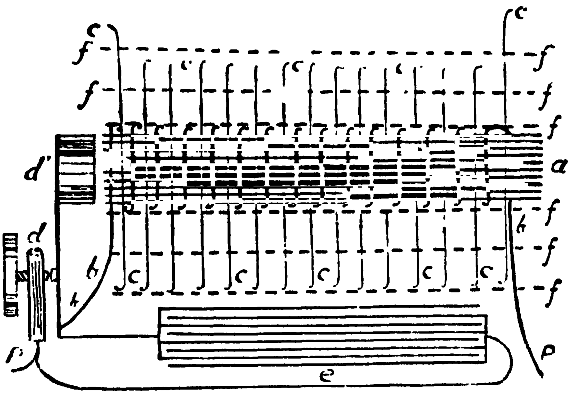


Fig. 13.

annealed soft iron wire, the diameter of the core being usually about 1/8 of its total length. It is essential to the good working of a coil that the iron should be exceedingly soft, so that it may quickly and fully take up the lines of force arising from the passage of an electric current, and as quickly return to its normal condition when the flow ceases. For this reason it is

usual to "anneal" the bundle of soft iron wires constituting the core by bringing it to a bright red heat in a clear fire and allowing it to cool very gradually afterwards. The function of the core is to concentrate the lines of magnetic force set up by the primary current in its flow round the coils of the primary wire, *b*, into a small compact space, which is occupied by the second winding, *c*. It also serves in all those cases in which a "trembling" contact breaker, *d d'*, is attached to the coil, to rapidly make and break contact between the battery (or other source of current) and the coils of the primary, which it does by virtue of acquiring magnetism while the current is on, and of losing its magnetism when the current is off.

When the two ends of the primary circuit P P are connected to a battery or accumulator, the current flows along through the contact screw *d* to the contact spring supporting the hammer *d'* round the coils of the primary *b b b b*. In so doing the current magnetises the core *a*. This attracts the hammer *d'*, and breaks contact between the spring and the screw on the pillar *d*. This causes the core to lose its magnetism, which, ceasing to pull the hammer *d'*, allows the spring to reassert its power, bringing it again in contact with the screw tip at *s*, when the same series

of movements recurs, and continues as long as current is supplied by the battery, and, as we have explained at § 10, the result of this making and breaking contact between the primary coil and the battery is to set up transient currents in the primary wire.

Surrounding the primary wire coils *b*, but carefully separated from them by the insulating material *f*, is the secondary wiring, consisting of several thousands of turns of fine wire, *c c c c*. These are not connected in any way to the primary coils *b b*, nevertheless by *influence*, at the instant that contact is made and broken on the primary circuit, currents are induced in the coils of the secondary; and these currents are higher in tension and smaller in quantity than those flowing through the primary coils, in the same ratio that the windings of the secondary exceed the windings of the primary.

We have also noticed that the current self-induced in the primary wire *b*, being *opposed* to the battery current, sets up a counteracting effect. The end served by the condenser *e* is to take up and store this self-induced current until the next contact takes place, so as to minimise the lowering of magnetisation, which would otherwise take place in the iron core at these instants. By this means, the pressure of E.M.F. set

up in the secondary wire is greatly exalted when the "breaks" take place, so much so, that a coil that will barely give $\frac{1}{16}$ in. spark without a condenser will easily furnish an inch spark if fitted with a suitable one. The condenser *e* consists virtually of two sheets of tinfoil separated from each other by some insulating material, usually *paraffined paper*. In order that it may take up the self-induced current set up in the primary, these two sheets of tinfoil are connected respectively—one to the beginning of the primary wire *b*, where it joins the spring of the contact-breaker *d'*, and the other to the pillar carrying the screw of the contact breaker *d*. In order to save space it is usual to cut the tinfoil sheets into many squares, and to form two separate booklets by joining two sets of half the number of sheets along one edge, to lap the pages of one book into the pages of the other, separating each page with a sheet of paraffined paper. The last essential we have to consider is the insulation *f f*. This is perhaps the most important of all. When it is remembered that to produce a ½ in. spark in air, a pressure of 25,000 volts is needed, it will be abundantly evident that to withstand the pressures set up in ¾ in. or 1 in. spark coils, the insulating material must be of the very best, and must be used in such a way as to

insure the highest insulation at those points wherein the tendency to leakage is great.

Tape dressed with shellac varnish is the insulation usually employed between the iron core and the primary wire. The primary wire itself may be either cotton or silk-covered; in either case it should be well basted with melted paraffin wax. This excellent insulator is also used to saturate the paper separating each layer of secondary wire, and also to seal up the heads of the coil. Paraffin wax, when employed for insulating purposes, should be preliminarily melted up with some dry powdered chalk, allowed to settle while still fluid, and poured off from the dregs. This treatment removes any acid which might be present in the commercial article. As paraffin when at all burnt is not nearly so good an insulator as when in its normal state, the greatest care must be taken not to overheat it. For this reason it is advisable to melt it, and keep it melted, *à bain Marie*, or in a water-jacketed vessel.

The insulation between the primary and secondary windings should be *ebonite*, either in the shape of a thin, cylindrical, hollow tube, made all in one piece, and which fits tightly over the wound primary, or else as a tube, made by rolling thin ebonite sheet (about

$\frac{1}{64}$ in. thick) tightly round the primary, and fastening down the edge with Prout's elastic glue, applied with an iron sufficiently hot to melt it. Seven turns of sheet of the afore-mentioned thickness will give sufficient insulation. This tube should extend quite to the end of the core, in those coils in which a contact-breaker is employed *on* the coil, and should project ½ in. at each end *beyond* the core in those in which the contact is broken by mechanical means, independent of the coil. The "heads" of the coil, to which the outer connection, or "terminals," are affixed, should also be of ebonite, as also the outer case or jacket.

Although it *is* possible to wind a serviceable coil with *bare* copper wire for the secondary, depending only on the intervening air as the insulation, yet as this requires a special "spacing" winder, to insure each succeeding turn of wire lying at a determinate distance from its neighbour, we shall not make any further mention of this, except to advise our readers who may by chance have to repair a coil wound with *bare* wire, to discard this, and rewind with silk-covered wire of the same gauge. We therefore recommend silk covering as the insulation of the secondary, supplemented with copious basting with melted paraffin-wax.

We summarise the contents of this section by saying that when a current is interrupted in its passage along a coil of primary wire surrounded by a coil of secondary wire, an induced current is set up in the coils of this secondary wire, and can be drawn off from its extremities; that this current is transient and manifests itself at the instant of making and breaking contact only at the primary; that the pressure of the current thus set up bears the same relation to that of the original current, as do the number of turns of wire contained in the secondary to those contained in the primary. Also that, to minimise the "backlash" effect of the self-induction in the primary itself it is necessary to use a condenser; and, lastly, that the most perfect insulation of the secondary is absolutely essential to the production of a good long spark. We can now turn to the constructional details.

§ 17. We will take as our first example a coil capable of giving sparks of about 1 in. long *in air*, since by varying the quantities of the wires used, and the general dimensions of the parts in proportion to the length of spark required, coils capable of giving ½ in. or ¾ in. sparks can be constructed.

We will begin by describing a coil fitted with "trembler"—that is to say, a contact-breaker actuated

by the iron core itself, and then point out the modifications required in connections, etc., where it is intended that the contact should be made and broken by mechanical means only.

§ 18. The core should consist in a bundle of perfectly straight soft iron wires, 7 in. long, sufficient in number to make a solid cylinder ¾ in. in diameter. To make this a couple of brass curtain-rings ¾ in. inside diameter should be procured, the iron wires placed in these, while being held at about 6 in. apart. When the rings are nearly full additional wires should be cauticusly pushed in at the centre of the extremities until no more can be inserted, and the rings fit quite tightly. Under this treatment the middle of the bundle may bulge a little. This can be remedied by binding tightly a turn or two of the same soft iron wire round the centre, and twisting the ends of this binding wire together. Care must be taken that the two ends of the bundle are perfectly level. If not so, they must be bound round, and filed until they are. The iron core should now be placed in a clear fire, until it gets red-hot; then the fire allowed to die down, go out, and get quite cold. This insures the thorough annealing of the iron bundle, a point of the highest importance.

The next operation is to bind this core tightly round with tape. Having pushed one of the rings down on the core for about an inch, from one extremity, one turn of tape, about ½ in. wide, is to be bound round the bared end, pulling as tightly as possible, continuing the winding spirally downwards towards the ring. An assistant will now push the ring further down, and remove any iron wire binders that may have been used, the tape winding being continued spirally towards the other end, as tightly as possible, until both rings have been drawn off, and the tape bound round from end to end. The termination of the tape is now stretched down to the layer below, and cut off flush with the core.

To prevent the core rusting, and to insure good insulation between the iron of the core and the primary, it is desirable to soak the completed and taped core in melted paraffin wax until no more bubbles make their appearance. It should then be reared on end to drain and set.

§ 19. The next operation is to wind this core with two layers (about ½ lb.) No. 18 d.c.c. wire. Finer wire *may* be used, such as No. 20; but owing to the choking effect produced by the high self-induction of the finer wire, this necessitates the use of more accu-

mulator cells to get the same current. If coarser wire were to be used too much current would flow, and the accumulator would "run down" too quickly.

The core may be wound with this primary wire either entirely by hand, or better, by driving a French nail some distance in the centre of the iron bundle at one end and a flattened iron wire at the other, then supporting the core by these two projections between the slits made at the top of two standards erected on a baseboard. The wire end should be bent into the shape of a crank or handle, so that a rotary motion may be easily imparted to the core. Fastening down one end of the No. 18 wire by tying, at about ½ in. from the extremity of the core (leaving about 3 in. free for after-connection) the operator winds on tightly, evenly, and closely one layer of the said wire, until he reaches to within ½ in. of the other extremity of the core, when, winding always in the same direction he winds on a second layer, riding over the first, and when he arrives at the starting extremity, he ties the end firmly down, and cuts off the wire, leaving as before a free piece, 3 in. in length. The wound core is again treated as before, with a bath of melted paraffin wax, then reared on end to drain and set.

§ 30. We now turn our attention to the insulation

between the primary and the secondary. This is of the highest importance, and a little care expended on this part will be well repaid by the greatly superior results in point of spark length, and by the durability of the coil when once made.

If possible, an ebonite tube of sufficient inside diameter to allow the wound core to be slid into it with a fair fit should be chosen. This should have a wall thickness or "shell," from $\frac{3}{32}$ in. to $\frac{1}{8}$ in. The length should be that of the iron core. If the coil is to be of the square pattern, with trembler and fitted with heads, the two ends of the tube should have screw-threads cut in them for a length of about $\frac{3}{8}$ in., on which the heads can afterwards be screwed.

If circumstances prevent the operator from procuring a solid tube, a very good substitute can be made by taking a strip of very thin sheet ebonite (about $\frac{1}{64}$ in. thick) as wide as the core, and of sufficient length to make about seven turns round the core. A wooden mandrel or form, about $\frac{1}{4}$ in. less in diameter than the wound core, and an inch or two longer, is now procured. The sheet of ebonite is placed in a vessel of boiling water. This will soften it sufficiently to enable it to be rolled tightly round the wooden cylinder, so as to form a tube, which must be tied down

tightly with wide tape, laid on spirally. When the tube is quite cold and hard, the tape will be removed, when it will be found that the ebonite will retain its shape—viz., of a tube rather less in diameter than the wound core.

This tube must be allowed to dry thoroughly from any adherent moisture, and then coaxed over the wound core, which it will embrace firmly, by reason of its springiness. The extreme outside lap of the ebonite forming this tube should be lifted slightly, and a brush, charged with a thick solution of shellac dissolved in methylated spirits, run along the edge, for a depth of about ¼ in. The lap should then be allowed to fall back in its place, and pressed well down. After this, the tube should again be tightly bound round with tape and set aside to dry. By this means a well-fitting insulating-tube is obtained. A built-up tube of this type is quite equal to a solid tube as regards its insulating powers, etc.; and for coils to which it is not necessary to screw on heads, quite as convenient, but of course, it would be impracticable to cut a thread on such a tube, so that, in using a built-up tube it will be necessary, if heads are to be fitted, to put plain holes through these latter, and cement them on with hot melted shellac or good sealing-wax.

§ 21. The tube having been fitted and the tape removed, the winding of the secondary constitutes the next step. For this purpose a winder must be constructed. On a board 9 in. long, 6 in. wide, and 1 in. thick are erected two standards, one at each end centrally. These standards should be 8in. high, 1 ½in. wide, and ½ in. thick. Through the centres of the lower ends of these standards, at about 2 in. from the base, and exactly facing one another, ⅛ in. holes should be drilled to admit of the passage of a ⅛ in. steel rod, which serves to go through a central hole of the bobbin containing the silk-covered wire, with which the secondary is wound.

At a height of about 4½ in. from this first pair of holes a second pair is drilled in the standards, also exactly opposite one another, and a slit ⅛ in. wide cut down, to reach these holes from the top ends of the standards. These serve to support a second rod, which, in its turn, carries the core, etc., on which the secondary wire is to be wound. But this second rod is not all in one piece. On the one side it consists in an ⅛ in. hard iron round rod, about 4½ in. long, nicely pointed at one end, which can be pushed in the centre of the iron core between the iron wires, and at the other end, of a rod made of No. 16 soft iron wire about

1 ft. long, doubled at its middle, and twisted together nearly up to the end, so as to form a kind of two-tined fork at that extremity, where the "tines" must be bent forward parallel to each other, at a distance of about ½ in. apart. At about the middle the twisted rod is bent twice at right angles, so as to form a crank or handle. The prongs of the fork having been pushed in between the iron wires of the wound primary, at the opposite end to which the pointed rod was forced in, the primary with its ebonite insulation on, is slung between the slits in the standards, and is ready for winding by turning the cranked handle.

The wire to be used for winding the secondary is No. 36 silk-covered copper. If *good* single-covered can be procured, free from unevenness, and particularly from bare places, it is to be preferred to double-covered, as it lies closer, and hence nearer to the intense inducing field; but if the covering be faulty, it will be better to have recourse to double-covered wire. The quantity of wire required will be about ½ lb. for a ½-in. spark coil, or about 1 lb. if the coil is intended to give 1-in spark.

Before proceeding with the actual winding, it will be needful to prepare sufficient paraffined paper to place between each layer of wire in order to insulate

the succeeding layers the one from the other. As we shall require paraffined paper for the condenser also, it will be advisable to make the whole at one operation.

§ 22. To prepare paraffined paper, some twelve or fourteen sheets of good white demy paper, free from specks and holes, must be chosen by examination between a strong light and the eye, all defective sheets being rejected. The size should be about 22 in. by 18 in. About thirty-nine strips 9 in. long by 6 in. wide will be required for insulating the secondary, and about sixty squares 5 in. long by 6 in. for the condenser. By laying the sheets of paper evenly and squarely one over the other on a flat board, these two sizes may be cut out with the aid of a straight metal rule and sharp knife at one operation for each size. A tin dish (a large baking dish will do nicely) rather larger than the sheets should now be selected, and in this should be placed sufficient paraffin wax (previously rendered neutral by chalk, § 16) to cover the bottom to a depth of ½ in. when melted. The dish should then be cautiously heated, preferably *à bain Marie*, until the wax is all fused. The paper should then be introduced sheet by sheet, and, when thoroughly permeated, withdrawn a sheet at a time, care being taken

to remove all superfluity of wax by drawing the paper over the edge of the tin, and allowing it to drain by one corner, into the dish, which must be kept at one steady temperature (about 150° Fahr.) during the whole of the operation. After draining each sheet should be hung up by one corner, with a pin bent into an S, on a line to set hard. If any sheets are unduly thick at places, or show blobs of congealed wax, these should be placed between sheets of thick white blotting paper, and run over with a fairly hot iron.

The bobbin of No. 36 silk-covered wire is now placed between the standards of the winder, and supported by running the lower rod through the central hole in the bobbin. The beginning of the wire is now found and unrolled. Three or four inches of this is coiled into a tight helix round a small pencil, which is then withdrawn, leaving only a helix of wire. This is taken up to the primary, which has been previously slung between standards, as directed above, and the wire tied to the ebonite tube, say at the left-hand extremity, at about ½ in. from the end, leaving the helix free for future connection to terminals, etc.

Now by turning the handle, the wire can be wound off the lower bobbin and caused to coil round the ebonite tube. Before commencing to wind, it will be

necessary to put a turn or two of paraffined paper tightly around the ebonite tube, so as to get a perfectly smooth surface to wind on. When the edge of this paper has been pulled very tightly, it can be made to adhere to the paper below by gently warming along the edge with a hot iron, which will melt the wax and cause it to adhere. The handle can now be turned and the wire wound on, the greatest care being taken to lay it on smoothly, closely, and without either gaps between coil and coil or any coil overriding the other. Kinks must also be avoided, as they are detrimental. Should any bare place show itself in the wire, this must be wrapped round with fine silk. Should a break occur, the broken extremities must be bared of covering, cleaned till quite bright with a bit of finest emery-paper, twisted together, soldered by the aid of a stout, hot copper rod and soft solder, aided by a little rosin. No soldering fluid may be used, as this would certainly cause the wire to rot and break. When the repair has been neatly executed, the joined portion should be carefully bound round with some fine floss silk to insure insulation. The winding must be continued until the operator reaches to within ½ in. of the right-hand end of the tube, when he will stop, and, fastening the wire so that it should not uncoil, he will

cover the layer of wire just laid on with a turn and a half of paraffined paper, taking care that the end of the wire running off the bobbin lies under the lap of the paper when this passes over it. The paper must be pulled very tightly and smoothly, so as to be perfectly cylindrical, and without any creases, and then fastened down, as was the first paper. Again turning the handle (always in the same direction), the operator winds on a second layer of wire, until he reaches the left-hand extremity, stopping, however, about two turns short of where he started. This is to cause the length of the coils to diminish slightly as the successive layers are wound on, with a view to preventing the upper layers sparking down, and short-circuiting to the ones below. Using all the precautions recommended above, the operator continues winding, putting on first the paper, then the layer of wire, then paper, and so on, until the whole of the pound of No. 36 wire has been coiled on, with the exception of about 6 in., which must be left free for future attachment to terminal.

To prevent uncoiling, two or three turns of paraffined paper should be rolled tightly round the last layer of wire, taking care to bring the free 6 in. end of wire out from between the turns of paper, where it

can, like the starting end, be coiled into a tight helix. Besides fastening the edges of the last lap of paper down by heating, it will be well to bind the whole round with a wide silk ribbon, laid on spirally, so as to reach from one end to the other, when it can be stitched down and any excess cut off.

The winding of the secondary being thus completed, the entire wound coil should be plunged bodily in a vessel containing melted paraffin wax. The temperature must not be allowed to exceed 150 degrees Fahr. If the vessel be deep enough to allow the paraffin to entirely cover the coil, so much the better; it may be left therein until no more bubbles appear. When this occurs the wax may be allowed to cool a little, until it is just beginning to get pasty, when the coil should be withdrawn, and set on end (over the vessel, supported by two side-sticks) to drain and set hard. Should the vessel be shallow, the coil should be set on end, and the upper end repeatedly basted with the hot paraffin-wax. The vessel may now be removed from the source of heat, allowed to cool as before, the basting being continued until the paraffin begins to get pasty, when the coil can be set up to drain, as previously recommended.

§ 23. The condenser next demands our careful

attention. From $\frac{1}{4}$ lb. of ordinary tinfoil we cut out 50 rectangular sheets $6\frac{1}{2}$ in. long by 4 in. wide, and having placed our paraffin-paper sheets (see § 22), the size of which is 6 in. by 5 in., close at hand, we lay three of these squarely one over the other on a flat board. In order that the sheets should not shift during the subsequent building-up of the condenser, it will be well to drive eight stout pins, upright, into the board just round the edges of the paper, two at opposite sides of each corner.

We now lay a tinfoil sheet over the paraffin paper so as to leave a margin of about $\frac{1}{2}$ in. wide all round the tinfoil, except on the *left-hand side*, where the tinfoil should extend beyond the edge of the paper by 1 in. Over this is placed a second sheet of paraffined paper, squarely between the pin-guides; then a second sheet of tinfoil. But this time the overlapping inch of tinfoil must be to the *right-hand side* of the operator. Now another sheet of paper is placed over the last tinfoil, over which is laid another tinfoil, with *its* overlap to the left; and so on, paper, tinfoil, paper, tinfoil, until the whole tally of sheets have been laid on.

Particular care must be taken that the sheets of tinfoil extend alternately to the left and to the right of the covering papers.

Three or four sheets of paraffined paper should now be laid over the whole, and a rather warm iron (just sufficiently heated to soften the paraffin wax on the paper, but not enough to make it run) laid on the top. In order to prevent adhesion to the iron, it will be well to place a sheet of blotting-paper, of the same size as the paraffined-paper sheets, between the iron and these latter. The iron should be left on until quite cold. Removing the iron and the guide pins, the operator now passes a thin knife-blade between the board and the first paper, and thus lifts the condenser, without disturbing the sheets. If the last operation has been nicely done, the sheets will adhere together, and form a fairly solid block. If not, it will be advisable to put a long "binder" of paraffined paper round the condenser about its narrower width, leaving its tinfoil ends projecting at the longer extremities. This binder can be fastened down upon itself by running a little paraffin wax along its edge, with a moderately warm iron.

When all is set and cold, two straight pieces of No. 20 copper wire, about 6 in. long, are made perfectly clean, and laid one on each of the projecting ends of the tinfoil sheets. These are carefully smoothed out, and then rolled round the wire in the shape of a

cigarette, with the wire as a core, until by rolling the edge of the condenser is reached. The wires should project about 2 in. beyond the rolled tinfoils. A needle should now be threaded with some clean *bare* No. 36 or 38 copper wire, and the tinfoil rolls stitched neatly round the wire cores. These latter serve for making connections between the coil wires and the condenser.

In making the condenser the following points require particular attention:—(1) The paper must be free from all pin-holes or thin places. (2) It must be well and *evenly* coated with paraffin-wax, but must not have any excess or "blobs." (3) The tinfoils must leave a margin of paper all round except at overlap extremities. The overlaps, or "tabs," must be alternately to the right and the left of the length of the paraffined sheets. (4) Each sheet of paper, as it is laid on, should be pressed down firmly and squarely (if needful, aided by a *clean*, warm iron), so as to form a solid block. (5) No paraffin should be allowed to flow between the extending "tabs" of tinfoil; otherwise good metallic contact cannot be made to the coil itself. (6) Great care should be exercised not to tear the protruding tinfoil extension.

§ 24. We can now take up the contact-breaker or

"trembler." As our coil is to be as compact as possible, we shall do away with the stand or base, on which ordinary Ruhmkorff coils are mounted, and let all the adjustments and accessories be fitted to the coil-heads, etc., themselves. The contact-breaker consists of two portions, (*a*) the vibrating spring, with its hammer and base, and (*b*) a brass strap, which strides over it, carrying the contact screw and lock nut. The former should be made of a piece of steel (a clock-spring straightened out does very well) about $\frac{1}{50}$ in. thick, ⅜ in. wide, and 2 in. long. A ⅛ in. hole is drilled in the centre of each extremity of this, and a bare $\frac{1}{16}$ in. hole in the middle of the strip. It is needless to remark that the steel must be softened by heat to admit of these holes being drilled, and that the finished spring must again be tempered to a deep blue and plunged in water. From a piece of soft iron rod is now cut the hammer, which should be ⅝ in. in diameter, and ½ in. long, the two ends being filed perfectly flat and parallel. In the centre of this is put a hole (not reaching quite through), which must be tapped to take a ⅛ in. Whitworth screw. The iron is then carefully softened and annealed by bringing to a red heat and gradual cooling. While this is going on we put a short piece of No. 16 platinum wire

through the small hole in the centre of the spring, when by gently hammering with a flat-faced hammer on a smooth steel anvil, we rivet the platinum in, causing it to spread somewhat on the upper surface, so as to form a stud or button, about 1/8 in. in diameter. This is to form one contact. A little square of brass is now filed up from a piece of 1/8 in. hard sheet, to form a base for one end of the spring. This should be 3/8 in. square, and have a 1/8 in. hole put through its centre, corresponding to the hole at one extremity of the spring. The annealed iron hammer is now cleaned and attached to the spring by a suitable short cheese-headed screw, care being taken that the iron bob be placed on the side of the spring opposite to that on which the platinum button has been splayed out widest. To fasten the contact-breaker down to the case of the coil, a similar screw (only rather larger) is selected to go through the holes in the spring and block. This screw should be fitted below with a small square or hexagonal brass nut, to enable contact to be made with one of the coil terminals, as described later on. The brass strap may be either a casting, or made from 1/8 in. sheet brass, bent four times at right angles, thus _|‾|_. It should be 1/2 in. wide, 3 1/4 in. long before bending, and 2 in. from end to end when

bent into shape. The feet should be ½ in. long, the height of the bridging piece ⅝ in. clear from the base, and the width of the opening ⅝ in. A ⅛ in. hole is put through the centre of each foot to admit the screws by which the strap is to be attached to the coil. A hole is also to be bored and tapped through the centre of the bridging piece, to take a ⅛ in. Whitworth brass screw, with ⅝ in. milled head. This latter screw must be fitted with a ¾ in. lock-nut, also milled

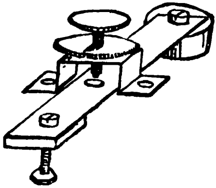


Fig. 14.

round its edge, and a $\frac{1}{16}$ in. hole drilled carefully for about ¼ in. up the centre of the stem of the screw, into which is fitted, by gentle hammering and burring, a piece of No. 16 platinum wire, which should project about ⅛ in. beyond the tip of the screw. The complete arrangement is shown at Fig. 14.

§ 25. We can now proceed to make the outer box or case, and fit the coil therein, making the proper connections to condenser, contact-breaker, and ter-

minals. The case may be made of any hard, well-seasoned wood, such as teak, mahogany, or walnut. If the coil has been nicely wound, it will not exceed in diameter 2½ in., in which case the inside dimensions of the box may be 3½ in. square, by 6¾ in. long. The wood with which it is constructed should be ⅜ in. thick when planed up, so that the external dimensions will be those of a square upright box 4¼ in. in the sides, and 7½ in. high, including the bottom and cover, which latter is not to be fastened down until the coil and condenser have been put in place. Should, however, through careless winding, the diameter of the coil exceed 2½ in., the width of the sides of the box must be correspondingly increased: otherwise there will not be space enough for the condenser to lie in without coming into dangerous proximity to the secondary wire. The sides and bottom of the box should be dovetailed together, as it is not advisable to use metal screws near the coil. The box may, or may not, be polished; but, in either case, to insure its being a good insulator, it should be allowed to soak for some time in melted paraffin-wax, previous to finishing. The bottom and sides of the box being of wood, as above described, the 4¼ in. square forming the top cover may be made

out of a piece of ebonite, ¼ in. or ⅜ in. thick, cut to fit squarely on the top of the box, and nicely polished. Holes will have to be put through this cover, two each side, to enable it to be screwed down to the box, one at each corner, just clearing the inside of the box, to take the primary and secondary terminals, one nearer the centre to take the screw destined to hold the vibrating-screw in place, and a pair for the screws holding down the brass strap. Besides this, one larger hole, very near the centre, to admit the passage of a portion of the iron core. The exact position of this latter will depend on the bulk of the wound coil itself, so that it may be left for perforation until the coil has been placed in the box.

§ 26. To assemble the parts of the coil in the box we proceed as follows. Starting with the wound coil, we scrape away any excrescences of paraffin wax from the cylindrical surface. We then draw out carefully the two free ends of the primary wire, which we had left for attachment, and having straightened them out, we pass each one through a short piece of ⅛ in. indiarubber tubing. In like manner, using every precaution not to break the wire, we find and straighten out the free ends of the secondary (No. 36) wire. These two ends should both be at the same

end of the coil as that at which the primary was started and finished. These wires should also be incased in indiarubber tubing. Two or three turns of thin ($\frac{1}{64}$ in.) sheet ebonite, of the same width as the wound portion of the coil, should now be wrapped tightly round the coil, and fastened thereto by binding round the silk twist, leaving the two primary and two secondary wire ends protruding at one extremity. We now take the condenser, and by gently coaxing it round a bottle filled with warm water, cause it to take a semi-circular shape, so as to fit partially round the coil, with *its* two wire ends projecting from the same extremity as the coil wire ends. We now place the condenser in the box, wires uppermost, keeping it as far away from the centre as possible. We then insert the wound coil, wire ends uppermost, as far away from the condenser as the space in the box will allow, but taking care that the entire bobbin stands perfectly upright, with the centre of the iron bundle in the exact centre of the side to which it is nearest. (The iron bundle should project about ¼ in. above the level of the box.) In order to retain it in this position previous to the next step, it will be well to insert a few wedges of paraffin paper between the coil and the condenser.

We now arrange the wires so that the primary ends stand out as far as possible from the secondaries, especially these two latter, from each other, as, if they are less than 1 in. apart, there will be a tendency to spark to each other. Having seen to this important point, we melt carefully some clean paraffin wax, not making it too hot (about 150°), and pour it into the box, so as to fill up all interstices in the case, and bring the surface of the melted wax up to a ¼ in. of the level of the top of the box. We can now make the ¾ in. hole in the ebonite top or cover of the case, into which the extremity of the iron core will enter, and allow the hammer of the spring to play in front of. By placing the iron bob centrally in this hole, we shall be able to mark the spot in the cover at which to make the hole for the screw holding down the spring and its little base-block. We now place the strap in position, striding over the spring, with the platinum-tipped screw touching the centre of the platinum boss on the said spring, and mark off and then drill the holes to receive the screws which serve to hold the strap in its place. As it is not advisable to use solder at any of these junctions, we must allow one of the strap screws to project a little beyond

the underneath of the cover, and fit it with a small nut.

The four terminals are now inserted near the four corners of the cover. The two primaries should be rather larger, and of a different pattern from those intended for the secondary; but all four should be fitted with nuts below to facilitate connections to wires without soldering. We now coil the ends of the secondary wires (previously incased in indiarubber tubing), each one respectively round a small French nail, so as to produce a neat helix. Withdrawing the nail, we do likewise with the two condenser wires. (This gives elasticity to the wire ends, and allows us to manipulate them, and also to close the cover without fear of breaking the wires.) Baring the ends of the secondary wire, and cleaning them bright with a bit of fine emery-cloth, we clench them under the nuts belonging to the secondary terminals. In like manner we connect the two ends of the primary wire, one to the nutted screw holding down the brass strap, and the other to the nearer large or primary terminal. Taking one of the wires proceeding from the condenser, we bare and clean it at about its centre, and here we pass it under the nut at the bottom of the screw that holds down the vibrating spring, carrying the remainder to

the other primary terminal, under the nut of which its bared and cleaned end is to be firmly clenched, any excess being cut off with the cutting pliers. Lastly, we carry the other condenser wire to the strap screw where we had previously put the first end of the primary wire, and having unscrewed the nut, we twist the wires together, and clench them both under the same nut. Care must be taken in making these connections—first, that the nuts clench firmly the wires; secondly, that the secondary wires are not severed in tightening up the nuts; thirdly, that the wires do not touch or cross each other at any point. The primary wires and the condenser wires (except only those two which are joined under the strap nut) will be sufficiently insulated from each other, where near, by the insertion of a piece of paraffined paper. This, however, is not the case with the secondary wires: these *must* be kept at as great a distance as practicable from each other, well covered in indiarubber tubing; otherwise leakage, even to the point of sparking across to each other, will be sure to occur. When we are satisfied that this is the case, we cautiously lower the cover, taking care that the wires do not get displaced, and screw down the cover by the eight side screws. Fig. 15, in which the outlines of the case are only

faintly drawn, will give a general idea of the arrangement of the parts, and the connection of wires. The cover is shown somewhat raised.

§ 27. If it be desired to mount the coil without the trembler, and to depend entirely on the mechanical

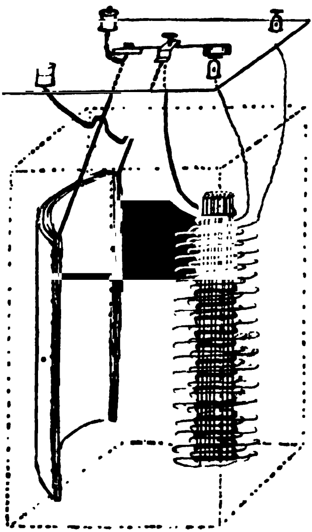


Fig. 15.

break for obtaining the spark, the mode of fitting up will be somewhat different. The case may take the form either of a box, as previously described, or, as more usual, of an ebonite tube of rather large diameter, fitted with flanged ebonite heads, about ⅜ in. of which enter into the tube up to flange or shoulder,

and can be fastened thereto by three small lateral screws. No contact-breaker will be required. The coil and the condenser having been got ready, as previously described, an ebonite tube of suitable size to contain both easily is obtained, of such a length as to contain the entire coil and iron bundle (which in this case need not be longer than the wound portion of the coil) without touching the cover. The primary and secondary wire ends having been drawn out as directed in the last section, one end of the secondary wire is taken through a small hole drilled near one edge of the cover, near to which is inserted one of the secondary terminals; and under the shank of this terminal the bared and cleaned wire is clenched. The tube, with its contained coil and condenser, is now turned with its open end uppermost, and the coil and condenser being supported upright, and as far as possible from one another, melted paraffin wax is poured in until the iron core is entirely covered, there being left protruding the ends of one secondary, the two primaries, and two condenser wires only. When the wax has set, and is quite hard, the ends of the primary wire nearer the iron core are bared, as also one of the condenser wires. The free end of the secondary wire (which for this purpose should

have been so coiled round the core so as to terminate at the opposite extremity to the one already secured to the terminal) is also bared. Then the starting extremity of the secondary is wrapped round the finishing end of the primary, and soldered thereto, using resin only as a flux. In like manner one of the condenser wires is coiled round the starting end of primary and soldered to it. The three ends of wire are now each respectively covered with indiarubber tubing, except just at the extremities, where they will have to pass through the upper cover and be connected to three separate terminals, situated at three equidistant points near the circumference of the cover. The cover should now be fastened in its place by three short lateral screws passing through the tube. The terminal to which the single condenser wire is connected should be marked K, the solitary terminal to which the single (or finishing) secondary wire was carried at the back end of the coil should be marked S +. In like manner the terminal to which the joined secondary and primary are connected may be marked A, while the one making connection to the conjoined primary and condenser wires will receive the mark B.

As it is essential to the proper working of the coil that the terminal S + should be in a positive state

when the coil is connected to its battery or accumulator, and as its condition will vary according to which pole of the battery is connected up to B and K respectively, it will be advisable to test this, and mark one of these terminals with + when found. This is easily done by connecting up the battery to A and K, first in the one direction and then in the other, an assistant

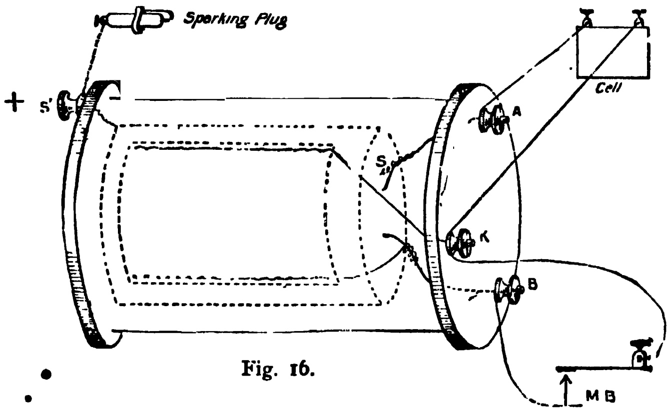


Fig. 16.

in the meantime *rapidly* making and breaking contact with a piece of wire between K and B, the operator, *not* the assistant, holding at the same time his knuckle at about ½ in. from S +. When the proper poles of the battery are being used, a fairly strong spark will pass from S + to the operator; but if the battery is wrongly connected, there will be either none at all

or else a very faint one. In performing this trial the operator should be careful not to come into contact with his assistant, otherwise they will both receive a pretty sharp shock; and the assistant must be careful not to leave the testing-wire in contact with both terminals K and B for any appreciable length of time, but simply to flash it across the two; otherwise he will heat the wire and run down the battery. In using such a coil, the terminal S + is taken to the ignition plug of the motor, the cell connected by its proper poles to A and K, while two separate wires connect K to the spring of the mechanical break, and B to the body of the engine respectively.

Fig. 16 gives a good idea of the disposition of the parts of a coil, intended to work without a trembler, after insertion in the tube or case.

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